

# COMPONENTS, SYSTEMS AND METHODS FOR FORMING A GASKETLESS SEAL BETWEEN LIKE METAL COMPONENTS IN AN ULTRAHIGH PRESSURE SYSTEM

## BACKGROUND OF THE INVENTION

### Field of the Invention

5                   The present invention relates to ultrahigh pressure fluid containment systems, and in particular, to components, systems and methods for sealing ultrahigh pressure fluids between components.

### Description of the Related Art

10                   Systems for containing fluids at ultrahigh pressures, such as those in excess of 15,000psi, can be extremely complicated and subject to failure after an unacceptably short life span. One example of an ultrahigh pressure system is illustrated in Figure 1, wherein a cylinder 10 is compressed by tie-rods 12 between a check valve 14 and a plug 16. A fluid at an ultrahigh pressure is contained within a cavity 18 (Figure 1a) that is sealed between the cylinder 10, the check valve 14 and the plug 16. Although various  
15                   methods have been used to provide a seal for such a configuration, as discussed below, the methods have shown to be insufficient.

                  As best illustrated in Figure 1a, an annular seal 20 fabricated from a sacrificial material of lower strength than the cylinder 10 and the check valve 14 is positioned between the two bodies to provide a seal. It has been found, however, that the  
20                   lower strength seal 20 requires frequent replacement, and that the stresses exerted by the seal result in early failure of the primary complements of the system. Such failures include cracks 22 formed in the bodies adjacent the annular seal 20.

                  In addition, because materials subjected to extremely high pressures expand, relative motion between the parts results in failure through spalling, galling, or fretting. As  
25                   best illustrated in Figure 1b, as the pressure within the cylinder 10 cycles between atmospheric pressure and ultrahigh pressures, the cylinder and the plug 16 expand and

contract. It has been discovered that, in the configuration illustrated in Figure 1b, the cylinder 10 moves at a different rate as compared to plug 16. As a result, during each cycle there is relative movement between the parts. Relative movement between parts of like materials in compression results in spalling, galling and fretting, each of which can damage one or both of the abutting components and shorten the life of the system.

Although this example is illustrated with a drawing of a plug, a cylinder and a check valve, it has been experienced in the industry that similar failures occur at other locations throughout an ultrahigh pressure fluid containment system. Accordingly, the invention discussed below is intended to solve such problems throughout the system.

## 10 BRIEF SUMMARY OF THE INVENTION

The present invention is directed toward components, systems and methods for sealing between components in ultrahigh pressure fluid containment systems. Embodiments of the invention allow a complete seal to be formed without a gasket between components of a like material. In addition, embodiments of the invention allow adjacent components to expand and contract without significant relative motion between the components, reducing damage and extending the useful life of the components.

One embodiment of the invention incorporates a pair of adjacent components, one having a tapered female mouth integrally formed thereon for engagement with a complementary tapered male mouth integrally formed on the adjacent component. Each of the mouths has a mating portion. One of the mating portions has a substantially linear cross-sectional profile that is angled between 40 and 68 degrees from a radial axis of the coupling. The other of the mating portions has a convex, curved cross-sectional profile that engages the linear profile of the other component at a substantially circular seal. The system allows components of like materials to be sealingly engaged with each other without the need of a gasket between the components.

Another embodiment of the present invention is directed toward a body having a tapered mouth configured to mate with a complementary mouth on a pressure vessel to form a circular seal therebetween. A contact angle between the adjoining

components is tangential to at least one of the components, the tangent measuring between 40 and 60 degrees from a radial axis of the component.

The present invention is also directed toward methods of manufacturing such components.

## 5 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Figure 1 is a diametric cross-section of an ultrahigh pressure containment system according to the prior art.

Figure 1a is an exploded portion of the system of Figure 1.

Figure 1b is another exploded portion of the system of Figure 1.

10 Figure 2 is a partial cross-sectional view of a pressure containment system according to the present invention.

Figure 3 is a cross-sectional view of a portion of a pressure vessel body and a portion of an abutting component, according to an embodiment of the present invention.

15 Figure 4 is a cross-sectional view of a portion of a vessel body and a portion of an abutting component according to an embodiment of the present invention.

Figure 5 is a graph illustrating a relationship between the contact angle between the abutting components, on one axis, and the relative motion between the components, on the other axis.

## DETAILED DESCRIPTION OF THE INVENTION

20 The present invention is directed toward components, systems and methods for creating fluid tight seals without the need for a gasket between components of like materials in an ultrahigh pressure fluid system. Many specific details of certain embodiments of the invention are set forth in the following description, and are illustrated in Figures 2-5, to provide a thorough understanding of such embodiments. One skilled in  
25 the art, however, will understand that the present invention may have additional embodiments, or may be practiced without several of the details described in the following description.

Figure 2 illustrates an assembly 100 of components from an ultrahigh pressure fluid containment system. The illustrated components are a check valve 102, a vessel 104, and a plug 106. Each of the components in the assembly 100 can be manufactured from like materials, such as stainless steel. As described in more detail below, the present invention allows the components to be compressed together to form a fluid seal between adjacent components without the requirement of a gasket. Further, the geometry of the components minimizes relative movement between the components as the pressure within the assembly 100 cycles.

Check valve 102 has an engagement portion 108 that abuts a complementary mouth 110 on the vessel 104. Similarly, the plug 106 has an engagement portion 112 that abuts a complementary mouth 114 on the vessel 104. Tie-rods (not shown) or other structures can be used to compress the check valve 102 and the plug 106 against the vessel 104 to form seals between the respective parts.

In the illustrated embodiment, the engagement portion 108 of the check valve 102, the mouths 110/114 on the vessel 104, and the engagement portion 112 on the plug 106 are all radially symmetric with respect to a radial axis "r" extending along the length of the assembly 100. During operation, the components of the assembly 100 are compressed in the axial direction "r" to form the subject seals.

Figure 3 provides a better illustration of the mate between the check valve 102 and the vessel 104. When viewed in cross section, the engagement portion 108 on the check valve 102 is convexly curved. The curve can be arcuate, elliptical, or of other suitable shapes. The mouth 110 on the vessel 104 that engages the check valve 102 has a substantially linear cross-sectional profile. The bevel of the mouth 110 of the vessel 104 is oriented at an angle " $\alpha$ " with respect to the radial axis "r". Accordingly, a contacting portion 116 of the check valve 102 corresponds to the tangent roughly equal to angle " $\alpha$ " when the check valve is aligned axially with respect to the radial axis "r". The seal between the check valve 102 and the vessel 104 consequently is in the shape of a circle. Depending on the radius of curvature of the cross-sectional profile of the engagement portion 108 of the check valve 102, and depending on the hardness of the material, the

circular seal between the check valve and the vessel 104 can form a circle of varying thicknesses.

Similarly, as best illustrated in Figure 4, the vessel 104 contacts the plug 106 to form a circular seal between the mouth 114 having a linear cross-sectional profile, and the engagement portion 112 having a curved cross-sectional profile. The linear cross-sectional profile of the mouth 114 of the vessel body 104 is aligned at an angle " $\beta$ " with respect to the radial axis " $r$ ". An inwardly facing alignment surface 118 on the vessel 104 mates with a complementary outwardly facing alignment surface 120 on the plug 106 to retain the plug in the proper alignment with respect to the vessel 104. The inventor appreciates that a wide variety of structures could be used to satisfy this purpose. Likewise, the inventor appreciates that the check valve could have a similar feature without deviating from the spirit of the invention.

The contact angles  $\alpha/\beta$  between the respective parts of the assembly 100 are designed to minimize relative movement between the respective components. As illustrated in Figure 5, the contact angles  $\alpha/\beta$  of the present invention are between 40 and 68 degrees, with a preferred range falling between 50 and 59 degrees, and an optimal angle of 54 degrees. The inventors appreciate that, depending on the material used for the components, the contact angles  $\alpha/\beta$  may vary slightly. After reviewing this present disclosure and figures, one of ordinary skill in the art could readily ascertain the optimal contact angles for any given material.

Embodiments of the present invention have numerous advantages over containment systems according to the prior art. The contact angle between the components, and the differing profiles of the adjoining parts (*i.e.*, a curved profile contacting a substantially flat profile), result in little or no relative movement between the abutting components as the pressure in the system cycles. The lack of relative movement eliminates or substantially reduces fretting, spalling and galling, all of which substantially increase the life of the components. In addition, the effectiveness of the seal in the present invention allows the components to be assembled without requiring a gasket or other intermediate structure. The inventors appreciate that such a structure could be inserted

between the abutting components. Due to the benefits of the present invention, however, such an insertion is not necessary. Still further, because there is little or no relative motion between the components, components made of like materials can be abutted directly against each other. This is a substantial improvement over prior art systems, in which like materials were avoided for contacting parts due to the historic problem of spalling and other failures.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.